Pushing architectural quality further

In this paper, the intentions thriving the implementation of computational modeling of building physics as it is approached in the Architectural engineering courses at Ghent University are discussed.
During the bachelor degree, courses focus mainly on integration of basic building physics feasibility in the architectural conceptualization. During the final bachelor year, students program their own simplified 2D models for internal condensation and thermal bridges in a spreadsheet, based on realistic detailing from buildings they studied in other courses. These models are intentionally kept both simplified and strongly mathematically based to nurture thorough comprehension of the physical background of problematic design options. Additionally, evaluation of energy performance with official EPB-software is incorporated in the courses because of its high relevance as a legal benchmark. All these models, including EPB, are (semi)static and thus offer only limited but nevertheless useful information on physical, legal, hygienic… viability of different options at reasonable complexity. Furthermore, they induce basic modeling skills as a basis for further development.
During the master's degree, the focus shifts from taxation of the feasibility of design decisions towards energetic performance as one of the starting points and validation criteria of the design process. For students who wish to specialize in the matter, elective courses and master's thesis projects on optimization, innovative techniques, passive building standards etc. are offered in which advanced dynamic modeling is used. These models offer an important input for this specific design process as they enable precise, nuanced validation of the robustness and sensitivity for certain parameters of different strategies in a given, very complex, situation.
By developing both innovative, more precise models for the master classes besides more powerful integration of modeling with design software (BIM) and robust predesign templates for the bachelor courses with master's student cooperation, the research team supports these courses in achieving output of the highest possible quality.

Introduction:

Architecture and modeling have a very intimate relationship since models, even more than the buildings they eventually represent, are the core object of architectural production. Each building that is build is unique and therefore, in contrast with product design, prototyping and beta testing is unrealistic. Architects employ models to represent and fully understand the different aspects of the project in the planning phase. 'Models' are here to be interpreted as representations in general, so they can be sketches, digital imagery, schemes as well as text, physical scale models and material samples. Design decisions are based upon data that is derived from these models. A fortiori, the project is even presented to contractors, legal administration and different stakeholders by sole means of this fictive image. Therefore, although some changes can be made during execution, it is crucial that the models, as means of communication, hold as much and as accurate information as possible. Architectural quality is or at least should nevertheless be defined by the aspects of the build object.
Because decisions and evaluations are based on the model, architectural quality in the planning phase is a function of the correlation the architect can establish between the representation and the actual build object. In light of this philosophical paradigm, the task of architectural education mainly consists of equipping students with skills to model their ideas and retrieve interesting

information from these models that accurately predicts the future state.

The questions that arise from this simple notion are to what extend computer technology can help develop these skills and in what context it offers the best performing model. Computers, by definition, offer superior computational power, which enables the user to access more, and more detailed, results. Moreover, the reduced calculation time allows for more reflection on the data. The actual impact of these expanded resources on design quality will be determined by aspects and quality of the pedagogical setting in which they are used.

This paper will focus on the implementation of computer models in building physics classes at Ghent University. The goals and the pitfalls of the implementation will be discussed for both the bachelor and masters degree programs. Concluding, further intentions of the research staff for the future developments will briefly be discussed.

Bachelor education:

During bachelor degree courses, students are supposed to adopt certain attitudes in assessing their own designs. The ability to present a technically coherent design is one of the specific goals this academic bachelor degree envisions, as stated in the description of the program in the academic educations register of the Flemish government (1). Two explicit subtargets are given, namely understanding the underlying scientific and practical principles of building and acquiring skills to represent (model) the design both graphically and digitally. This is clearly inspired by the philosophical context presented in the introduction. Through the different classes they start with the simple knowledge that energy supply is limited (fact), gradually forming a concept of a low energy building, relating this concept to energy saving measures and combining these measures in a low energy strategy for a building, thus ascending the taxonometry of knowledge as defined by De Block (2). The final goal of this path is that they attain a low energy attitude, always reflecting the consequences of their (design-) decisions in an energetic dimension. To achieve this, theoretical courses, practical exercises and a project are given. Within the same taxonometry (De Block), these approaches represent knowing, understanding and applying the matter respectively. The final stage, forming a well developed attitude for energetic reflection, is the achievement the students need to prove in the final design studio. Their design is rated on overall quality, detailing and performance both spatially and energetically.

While building physics is taught in an analytical way, students are asked to demonstrate their understanding of the matter trough solving simplified problems during the practical exercises. Here computers are first introduced. During exercises, students use simple spreadsheet programs to calculate the data needed to find the solution. The spreadsheet they develop at the end of an exercise is actually their first rudimentary model. By saving the file, they now possess a template for the calculation of, for example, the one dimensional heat loss through a wall. This may appear trivial and of little practical use since buildings are essentially three dimensional. Contrarily to this first intuitive appreciation, this model is of crucial importance, since it is the basis of all more advanced models, including the EPB-tool used for building licensing. The fact that students build this model them self is essential, since it makes sure that they understand how it relates to the physical phenomena it represents. Adding to this bit by bit, they eventually model a year-long condensation balance in a spreadsheet.
This model is then applied in the project to evaluate and improve the performance of their own design. In close collaboration with the design studio, a framework was created to apply the learned energetic concepts. At the introduction to the studio, the energetic feasibility of the design and detailing is stressed as an essential evaluation criterion. After a short conceptual phase, students get a new assignment, but continue working with the spatial concept and the self-made model in the building physics project to evaluate the performance of their initial proposals. The data generated is used to propose variants with better performance, which are elaborated further in a more technical perspective in a separate project. The final results of this continued development is then picked up again by the design studio and reintegrated in design. That last step has proved to be both the highest hurdle to take and the most decisive moment in the learning process, as students only then fully

appreciate the power of the model as a decision making tool and the impact their alternatives can have on the total design.

With the introduction of energy performance directive, the above mentioned strategy was abandoned slightly to give way to a more elaborate training in the legal EPB-software. Students were now no longer required to use their own models but followed an intensive workshop with the legal software. The assignment for the project was essentially the same. Although the now used software is much more elaborate, results of the project appeared poorer. The projects now featured a myriad of exotic techniques, but often lacked a coherent concept or a detailed analysis of the problem. In their oral presentation, students also proved to be less capable of explaining the fundamental physical processes determining their design.
Although these findings are purely subjective and not statistically analyzed, they indicate the importance of the tool. Architecture can essentially be described as a ‘wicked problem’ as described by Rittel and Webber (3) for which Munneke et al. (4) among others described the influence of different representational techniques in interactive argumentation. In the context of the EPB-software failure, the findings of Suthers (5) that students may loose themselves in the exploration of a complex tool, seem to apply.

Masters Degree:

The strategy for the bachelor degree lay-out, as discussed above, is designed to ensure that students produce architectural output of high (technical) quality, in accordance with the goals stated. Although the contemporary situation of the construction sector can only benefit from this benchmark, this is not sufficient to answer the acute need for innovation in building physics sprouting from energetic developments on planetary scale. The skills required to tackle this more fundamental branch are tackled in the master’s program. Students are free to explore one of the many fields touched in the bachelor program more profoundly and specialize themselves in this matter. Since an academic master’s degree presumes a capability to critically reflect and innovate existing knowledge, the mission statement of the masters includes developing the ability to conduct autonomous research in the field of the chosen specialty.

As we discussed above, experiments in bachelor degree courses pointed out that high quality output and the related high value engineering skills are only feebly triggered by simply using preformatted software. Better learning results are achieved when students program their own models based on their theoretical knowledge. In future projects the latter will obviously be preferred.
In light of the intentions of the masters program (1), the focus there is shifted towards more innovative research. Students are now expected to be capable of understanding the physical background of innovative systems and cooperate with the research team in different projects. Two main tracks of participation exist: either through elective courses or through the master’s thesis. Both focus on specific subjects like passive house standard offices, modeling the influence of surface treatment on efficiency of natural night ventilation or qualifying thermal comfort in a building.

Entirely different computer models are used for the various assignments. The models and the way they are approached can again be categorized twofold.
In the first category, models of a certain research component do not exist or are still highly experimental. The goal of the project then consists of developing, testing and validating the model. Since the models used in this particular context are very complex, individual students are no longer expected to program them themselves each time. Either they are responsible for the development of one part of the model in close cooperation with research staff and fellow students, or they validate the model that others created against available measurement data. Special attention in this particular stage goes to compatibility of the model with existing software environments like the academically well known TRNsys.
In the second category, the performance of certain techniques is validated. Here the weight of the investigation moves form the component to the building or system as a whole. The impact of certain components in the system and the sensitivity of the system to its characterizing parameters are qualified by modeling the whole of the system or building in a simulation suite. Rather than developing the model for the physical process, the goal is to build a model for feasibility. For this, the students can rely on data produced with earlier developed models for input. Here the use of elaborate and easy to use software environments in the preparatory stage is evident since this phase must be as short as possible. Nevertheless, experience with similar self-made models in the past is crucial to analyze the produced data correctly.

The emphasis that is put on innovative research and highly specialized modeling is of great value to the students as future architects and engineers with an appetite for the field of building physics, because it enables them to further nurture their recently acquired energetic attitude and familiarize themselves with state of the art technology. Evidently, their work is also beneficiary for the department as a research team, the scientific community and for society at large.

Next to this specialized research, which interprets the use of computer models essentially in the way described by Schmitt (6), new initiatives are deployed in the design studio of the master's program. The expertise based on the results of the specific research teams will in the future be implemented in the design studio of the masters program by means of a 'consulting group'. This group of researchers and professors with more technical background will assist the design studio sessions. Their task will be to confront students with technical issues in their design concept and relay them to the students and researchers who are working on that subject. This way, students benefit directly from the expertise and the models that are developed as described above. Interesting new concepts that arise from studio work, can of course also be a subject for deeper research. Next to this 'catering'-facility, a special type of specific research is conducted in the field of modeling itself. A special research project, in cooperation with the laboratory for information technology, now combines two essential models: the graphical representation of the design and the analytical model for energy performance.

This coupling, established in the international IFC-standard (7) is one of the steps that bring effective Building Information Modeling (BIM) (8) one step closer. 4 Master students are now using the beta version of this software in a design process to assess the possibilities and problems of this setup. If these test runs are successful, this software will be introduced in the design studios of the different programs for large scale testing of the impact this linked model can have on design output.

It is expected that, since the graphic model now gives important feedback on the energetic performance of the design, overall quality as described in the introduction will improve significantly.

Still, this in no sense lessens the importance of the model know-how acquisition process as it was introduced above. Although the model will report energetic inconsistencies, these can only be tackled by the student if he or she has thorough insight in the process that the data provided evaluate.

Complementary to this project, a new laboratory is initiated that will focus on computer generated physical models. The object of this research is the possibility to incorporate robotics in the construction process of a building. In the long term, the intentions are that students will be able to use the CAD-CAM technology in this laboratory in the design studio.

Framework:

A last important issue that has proven to be essential in the success or failure of the use of computer technology based models in both the bachelor and master's program is the supportive framework for students. None of the described projects are possible without student access to the technology and the software. Therefore, again in collaboration with the laboratory for information technology and the university ICT department, wireless internet access in the building of the architecture department, free access to modeling software trough a remote access application and bilateral agreements with software developers are established for all students. Although this provides access, these measures alone proved to be insufficient. Lots of student projects failed to deliver the expected output within the provided timeframe because of unexpected hardware problems or problems with the software functionality. A test during the academic year 2005-2006 proved that the presence of a staffer specifically skilled to deal with these problems had a significant impact on the results. Therefore, the department has decided to appoint a new staff member as soon as possible to attend to this need.

Conclusions:

In the introduction, modeling was described as one of the essential activities within architecture. In the corpus, intentions and implementation for computer models in the bachelor and master's program for architecture at Ghent University were discussed. The argumentation was presented that to push architectural quality to a higher level, the focus should be on continued development of better and more precise models. The mission of education in this context is twofold: equipping students with skills that enable them to actively take part in this continued research and help them develop an attitude to incorporate energetic reflection in every part of the design process. The underlying idea is that using computer models is only efficient when the user thoroughly understands how the model works. Only then can he of she interpret the produced data correctly and base decisions upon them. Several examples were given of practical organization of this approach in courses and within a broader practical framework. Future research will try to assess the effectiveness of the proposed measures with statistical data.

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